Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **APR 2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Large-Signal Code TESLA: Current Status and Recent Development**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Code 6840,4555 Overlook Avenue S.W,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002087. Proceedings of the 2008 IEEE International Vacuum Electronic Conference (9th) (IVEC 2008) Held in Monterey, CA on April 22-24, 2008. U.S. Government or Federal Rights License

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

13.1: Large-Signal Code TESLA: Current Status and Recent Development

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Abstract: *This work presents the current-status and the latest advances in the development of the large-signal code TESLA, mainly used for the modeling of high-power single-beam and multiple-beam klystron amplifiers.*

Keywords: large-signal code; multiple-beam klystrons; serial and parallel versions.

Introduction

The optimization and design of new high power, high efficiency klystron amplifiers relies increasingly on effective nonlinear simulation tools. One such tool is the large-signal code TESLA [1], which was successfully applied for the modeling of single-beam [2] and multiple-beam [3,4] klystron devices at the Naval Research Laboratory and which is now used by number of US companies. TESLA is a highly efficient fully electromagnetic 2D code, which solves self-consistently the electromagnetic field equations (including fields inside beam tunnel and cavity fields) and 3-D relativistic equations of electron motion. TESLA allows to model with high accuracy the main physics of complex devices with multiple resonant cavities and multiple electron beams. A typical TESLA run takes only a few minutes to complete for most problems under consideration, making the code useful as a design tool. The latest improvements in its models, algorithm and performance will be presented.

TESLA is a modern cross-platform scientific code, distributed now for Windows as an installable package with its own GUI, the core TESLA-solver and a set of useful post-processing tools. The Python based TESLA GUI makes the program user-friendly and simplifies the process of setting up input parameters. Interactive help explains the meaning of all input parameters and details of their proper specification. The interface is organized into related windows/sub-windows to make it easier to follow the logic for solving problems. The TESLA solver itself is a Fortran-95 code, computationally efficient in its inner structure with full dynamic memory allocation and highly optimized for computational speed performance. Post-processing tools allow graphical presentation for the majority of the simulation results obtained after the TESLA solver run. This includes the animation for the particles phase space and their motion through the device.

In addition, TESLA was recently transformed into a parallel code [5] to allow modeling of systems with multiple non-identical beams by calculation of their independent evolution in parallel in separate processes. The contribution of currents driving each gap from different processes, or non-identical groups of beams, is accumulated using MPI-calls and conversely, the cavity field is distributed to all gaps of every resonant cavity. In general, the predictions of the serial, non-parallel version of TESLA, which uses approximation of identical multiple beams and averaged values of R/Q in all beam-tunnels, and the parallel version of the code with non-identical beams, were found in good agreement with each other and with experimental data of MBK [4] (Fig.1). However, the parallel version of TESLA shows more pronounced effects of the transverse motion of slow particles at the end of the device and predicts more accurately particle wall intersection, which is important for high average power designs.

Wide availability of multi-core CPUs and multi-CPUs desktop computers makes it easier to use parallel codes in every-day modeling and design process. The results of parallel TESLA benchmarking as a dependence of the run-time versus the number of processes used in simulation is shown on Fig.2 on example of 4-cavity 8-beams MBK. When a sufficient number of processors are available, the full multiple beam simulation takes only slightly longer than for the identical beam approximation (curves 1, 3 and 4 on Fig.2). For example, using a cluster with 8 nodes for modeling of 8 non-identical beams (curve 1) the run time increase is only by 60% in comparison with the single-beam approximation.

This work was supported by the Office of Naval Research.

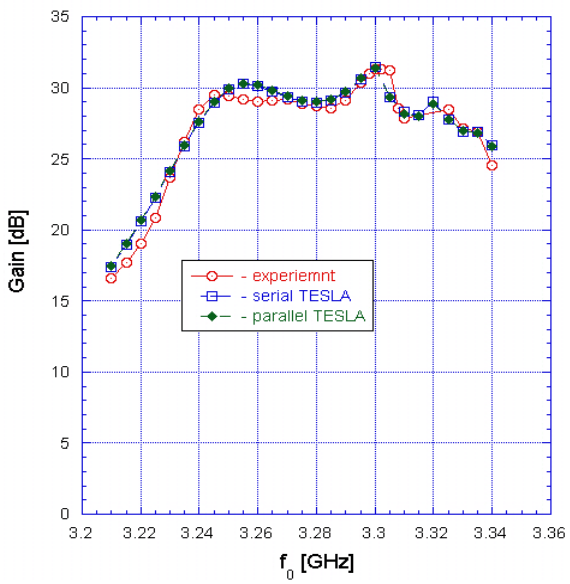

Figure 1. Comparison of predictions of serial (identical multiple-beams, averaged R/Q) and parallel (non-identical multiple-beams, measured R/Q) versions of the code TESLA with the experimental results for small signal gain (P_{in}=250W) of a fundamental mode 4-cavity 8-beam MBK [4].

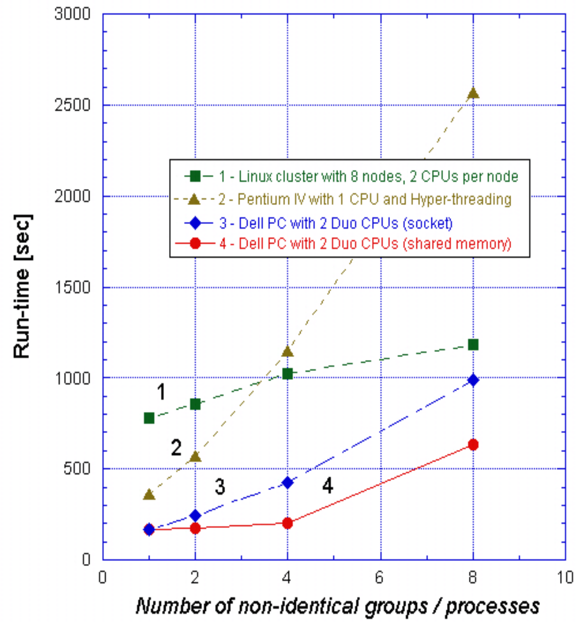

Figure 2. Benchmarking results for the parallel TESLA simulations of the 4-cavity 8-beam MBK configuration: curve 1 – running on Linux cluster with 8 nodes/2 CPUs per node (16 cores in total); curve 2 – on single CPU Intel Pentium IV PC with hyper-threading; curves 3, 4 – on dual CPU Intel Core 2 Duo PC (4 cores in total) using different MPI communication protocols.

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